Claims

[c1] A method for determining properties of a mixture of fluids, comprising:

(a)acquiring a plurality of nuclear magnetic resonance measurements from the mixture of fluids, each of the plurality of nuclear magnetic resonance measurements having a different value in an acquisition parameter for which at least one relaxation selected from the group consisting of longitudinal relaxation and transverse relaxation affects magnitudes of the nuclear magnetic resonance measurements;

(b)generating a model of the mixture of fluids;

(c)calculating a synthesized nuclear magnetic data set based on the model;

(d)comparing the synthesized nuclear magnetic data set with the nuclear magnetic resonance measurements; and

(e)adjusting the model and repeating (c) and (d), if difference between the synthesized nuclear magnetic data set and the nuclear magnetic measurements is greater than a minimum.

[c2] The method of claim 1, wherein the mixture of fluids comprise formation fluids.

[c3] The method of claim 2, wherein the formation fluids is in an earth formation.

[c4] The method of claim 2, wherein the formation fluids are removed from an earth formation using a formation tester.

[c5] The method of claim 2, wherein the formation fluids is in a core sample from an earth formation.

[c6] The method of claim 2, wherein the model comprises at least one component for a connate water phase and at least one component for an oil phase.

[c7] The method of claim 6, wherein the model comprises a set of amplitude components that define transverse relaxation time distribution of the connate water phase and a set of amplitude components that define transverse relaxation time distribution of the oil phase.

[c8] The method of claim 6, wherein the model further comprises one selected from the group consisting of an oil-based mud filtrate component and a gas

component.

[c9] The method of claim 1, wherein the acquiring uses a pulse sequence comprising an inversion recovery sequence and a Carr-Purcell-Meiboom-Gill sequence.

[c10] The method of claim 9, wherein the acquisition parameter comprises one selected from the group consisting of a recovery time RT in the inversion recovery sequence, a polarization time WT, and an inter-echo delay TE in the Carr-Purcell-Meiboom-Gill sequence.

[c11] The method of claim 9, wherein the model comprises a correlation function for each component in the mixture of fluids, the correlation function relates a measured magnitude, A_i, of the nuclear magnetic measurements with parameters used for the acquiring as follows:

$$A_i = A\left(1 - S * e^{-RT/T_1}\right) e^{-iTE/T_2}$$

where A is a full signal amplitude after full polarization along the static magnetic field, RT is an inversion recovery time in the inversion recovery sequence, TE is an inter-echo delay time in the Carr-Purcell-Meiboom-Gill sequence, T_1 is a longitudinal relaxation time, T_2 is a transverse relaxation time, and S is defined as:

$$S = 1 + IE * \left(1 - e^{-WT/T_1}\right),$$

where IE is an inversion efficiency and WT is a polarization time.

[c12] The method of claim 1, wherein the acquiring uses a pulse sequence comprising a saturation recovery sequence and a Carr-Purcell-Meiboom-Gill sequence.

[c13] The method of claim 12, wherein the acquisition parameter comprises one selected from the group consisting of a recovery time RT in the inversion recovery sequence, a polarization time WT, and an inter-echo delay TE in the Carr-Purcell-Meiboom-Gill sequence.

[c14] The method of claim 1, wherein the acquiring comprises:
inducing a static magnetic field in a region of investigation;
generating a series of radio frequency magnetic field pulses in the region of investigation, the series of radio frequency magnetic field pulses comprise an inversion recovery pulse sequence and a Carr-Purcell-Meiboom-Gill pulse

sequence; and

receiving signals comprising a train of nuclear magnetic resonance spin echoes, wherein a polarization time between the series of radio frequency magnetic field pulses is WT, an inter-echo delay in the Carr-Purcell-Meiboom-Gill pulse sequence is TE, a recovery time in the inversion recovery pulse sequence is RT, and the generating and the receiving are repeated a plurality of times each with a different value in at least one parameter selected from the group consisting of WT, TE, and RT.

[c15] The method of claim 1, wherein the acquiring comprises:

inducing a static magnetic field in a region of investigation;

generating a series of radio frequency magnetic field pulses in the region of investigation, the series of radio frequency magnetic field pulses comprise a satuation recovery pulse sequence and a Carr-Purcell-Meiboom-Gill pulse sequence; and

receiving signals comprising a train of nuclear magnetic resonance spin echoes, wherein a polarization time between the series of radio frequency magnetic field pulses is WT, an inter-echo delay in the Carr-Purcell-Meiboom-Gill pulse sequence is TE, a recovery time in the saturation recovery pulse sequence is RT, and the generating and the receiving are repeated a plurality of times each with a different value in at least one parameter selected from the group consisting of WT, TE, and RT.

[c16] The method of claim 3, further comprising (f) deriving, from the model, at least one porosity selected from the group consisting of water-filled porosity, oil-filled porosity, total NMR porosity, free-fluid porosity, and bound-fluid porosity of the earth formation.

[c17] The method of claim 3, further comprising (f) deriving, from the model, at least one saturation from the group consisting of water saturation and oil saturation of the earth formation.

[c18] The method of claim 3, further comprising (f) deriving, from the model, viscosities or diffusion constants of oil constituents of the earth formation.

[c19] A method for logging an earth formation surrounding a wellbore, comprising:
(a)lowering a nuclear magnetic resonance instrument into the wellbore;
(b)inducing a static magnetic field in a region of investigation;
(c)generating a series of radio frequency magnetic field pulses in the region of investigation, and receiving signals comprising a train of nuclear magnetic resonance spin echoes in response to the series of radio frequency magnetic field pulses, wherein the generating and the receiving are repeated a plurality of times each with a different value in an acquisition parameter for which at least one of the longitudinal relaxation and transverse relaxation affects magnitudes of the signals;
(d)generating a formation model that includes at least one component for a connate water phase and at least one component for an oil phase;
(e)calculating a synthesized nuclear magnetic data set based on the formation model;
(f)comparing the synthesized nuclear magnetic data set with the nuclear magnetic resonance measurements; and
(g)adjusting the formation model and repeating (c) and (d), if difference between the synthesized nuclear magnetic data set and the nuclear magnetic measurements is greater than a minimum.

[c20] The method of claim 19, wherein the series of radio frequency magnetic field pulses comprise an inversion recovery sequence and a Carr-Purcell-Meiboom-Gill sequence.

[c21] The method of claim 19, wherein the series of radio frequency magnetic field pulses comprise a saturation recovery sequence and a Carr-Purcell-Meiboom-Gill sequence.

[c22] The method of claim 19, wherein the formation model further comprises one selected from the group consisting of an oil-based mud filtrate component and a gas component.

[c23] The method of claim 19, wherein the formation model comprises a set of amplitude components that define transverse relaxation time distribution of the connate water phase and a set of amplitude components that define transverse

relaxation time distribution of the oil phase.

[c24] The method of claim 19, further comprising (h) deriving, from the formation model, at least one porosity selected from the group consisting of water-filled porosity, oil-filled porosity, total NMR porosity, free-fluid porosity, and bound-fluid porosity of the formations.

[c25] The method of claim 19, further comprising (h) deriving, from the formation model, at least one saturation selected from the group consisting of water saturation and oil saturation of the formations.

[c26] The method of claim 19, further comprising (h) deriving, from the formation model, viscosities or diffusion constants of oil constituents of the formations.